soft (electronics) harvard GSD fall 2003 prof. sheila kennedy

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solar cells + interfacing

oct.11TH 2003

sloan kulper, technical instructor

"welcome to the lecture notes for
our first instructional session.

today we will discuss:

a. structure

b. basic applications

c. handling + safety

d. theory (optional)"

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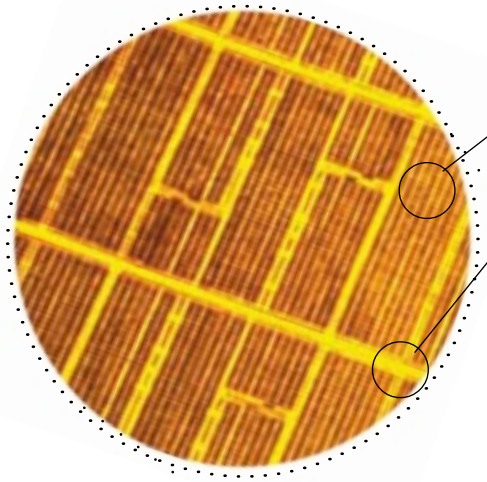
"photo-voltaic

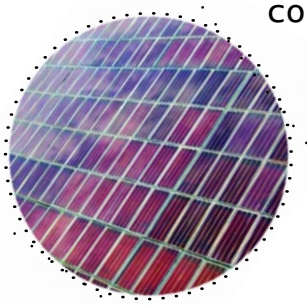
(or solar) cells absorb the visible wavelengths of natural or artificial light and produce voltages at their terminals that can be used for many applications.



they consist of a flat sandwich of silicon with a copper or silver wire mesh running over the surface...

(micro)

each of which makes either series or parallel connection its neighbor.



(macro)

solar panels

are arrays of PV cells. the voltage that an entire panel produces is equal to the number of cells linked together in series. when linked in parallel, each cell increases the maximum output current of the panel."

(landscape)

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typical voltages

for the type of solar panels we might consider using for this project are between 6V (a cd player's) and 30V (a stereo amplifier's) .

6V -> 30V

typical currents

that these solar panels could supply in full sunlight are between .1 and 1 Ampere, usually written as 100mA (enough for 5 LED's) and 1A (enough for a dim lightbulb) respectively.

100mA -> 1A

typical power

output, or wattage, is thus between .6W (cd player) and 30W (a dim lightbulb). thus, storage of energy rather than raw power output is key.

.6W -> 30W

typical area

is between 15"sq (a mini battery charger) and 800"sq (a small pool heater). area is roughly related to the square of the wattage, but that is a very rough relationship."

area ~= wattage^2

15"sq -> 800"sq

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different types

of solar panels are available on the market. all solar panels share the same basic design, but offer various advantages and disadvantages depending on their materials. I quote http://pkys.com/Solar%20power.htm :

monocrystalline

cells consist of thin slices cut from a single crystal of silicon. they have the highest efficiency and are usually the most expensive, they have the highest output for a given surface area and can last as long as 25 years.

polycrystalline

cells are sliced from a cast silicon block and have an appearance of shattered glass. they have a lower efficiency but they have a similar life span to the monocrystalline types while sometimes being a bit cheaper per watt.

amorphous

cells are made by placing a thin film of active silicon on a solid or flexible backing, typically a thin stainless steel sheet. they have the lowest efficiency. This translates to greater surface area for a given output. However amorphous panels do allow for more mounting options especially when using the flexible types. They do usually tolerate partial shade better than the other types because they have internal diodes that essentially turn off the shaded cells.

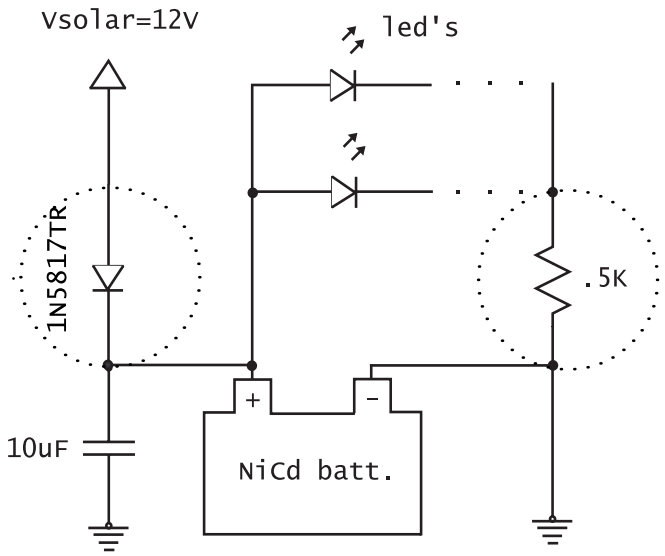
basic applications

of solar panels mostly revolve around either supplying low power devices or storing collected current during illuminated hours in a battery for use during dark hours.

for example, the solar globe yard light has gained in popularity due to it's elimination of the need for both outdoor wiring and frequent battery replacement."

circuit design

of the solar globe yard light is probably something similar to the following:



there are a few basic rules at play here:

1. ohms law ($V = IR$, $P = IV = I^2R$)

   LED's should be current limited to below 40mA - in this case, I = 12V/500 = 24mA

2. parallel vs. series led's

   in parallel, led's consume more current, while in series, they require a larger voltage supply

3. blocking diode

   a 1N5817TR Schottky diode, or similar low-forward voltage drop diode should be placed in series like this with every cell

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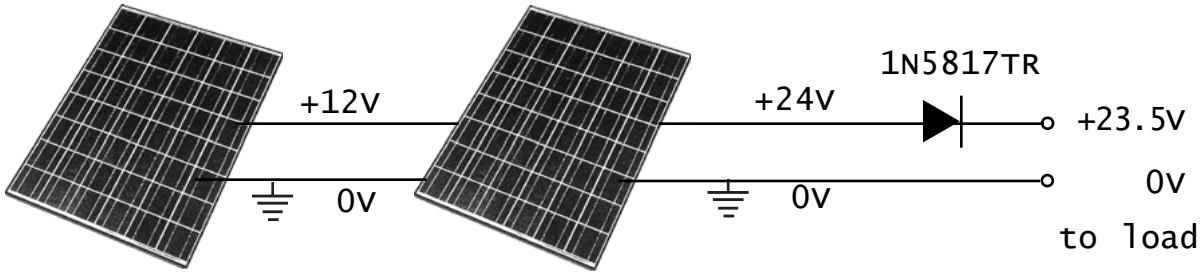
two configurations

for using solar panels in your projects include series/parallel - both deliver the same power output.

series panels sum voltage



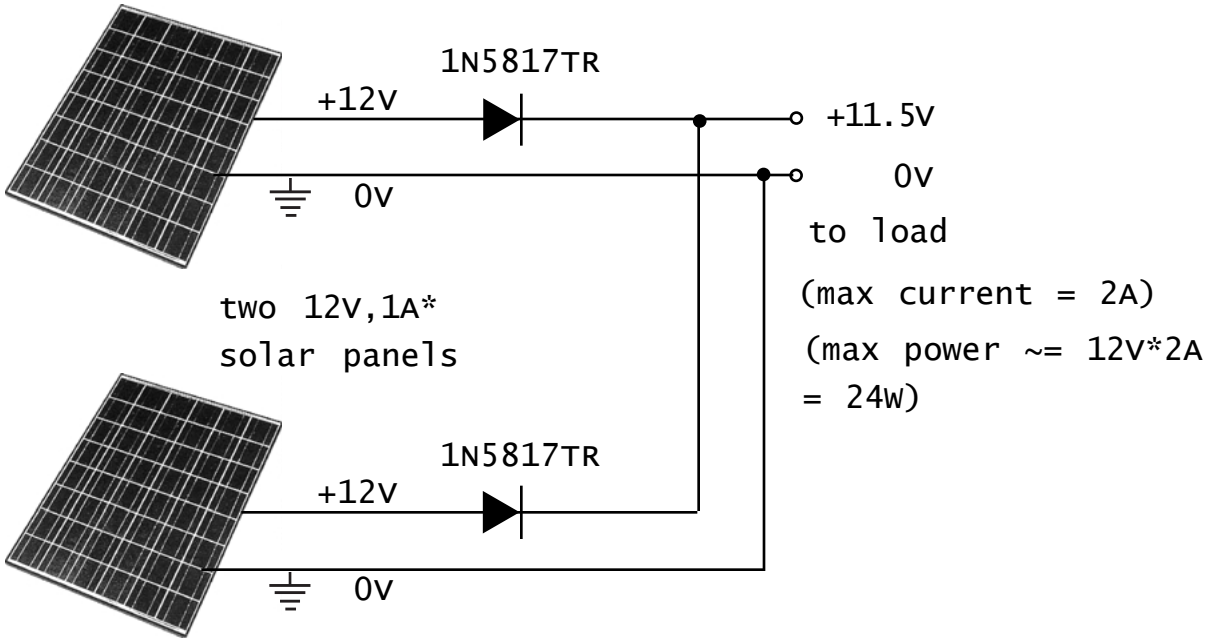
12V,1A* solar panel

12V,1A* solar panel

(max power ~= 24V*1A = 24W)

(current rating describes the maximum capacity of a panel, not what it delivers at all times - unlike it's voltage rating)*

parallel panels sum max. current



two 12V,1A* solar panels

(max current = 2A)

(max power ~= 12V*2A = 24W)

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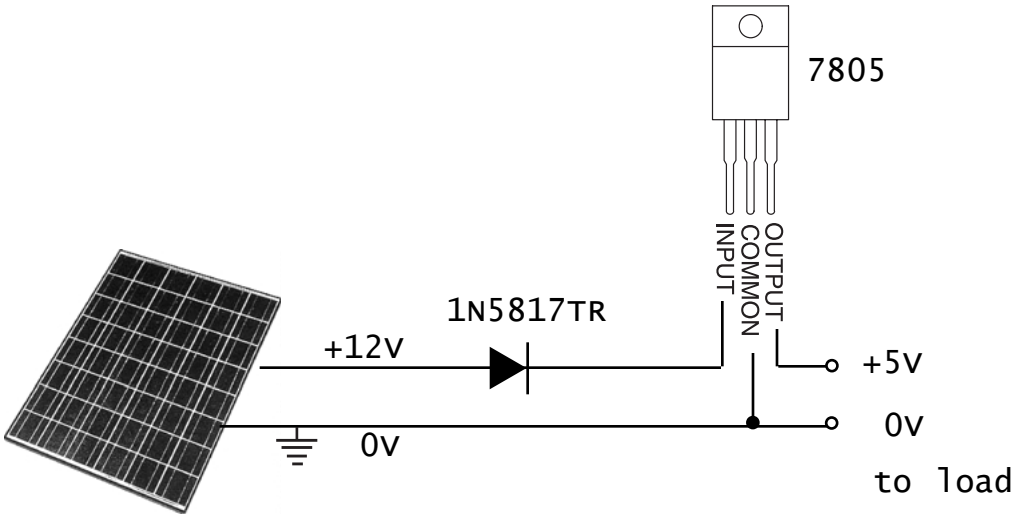
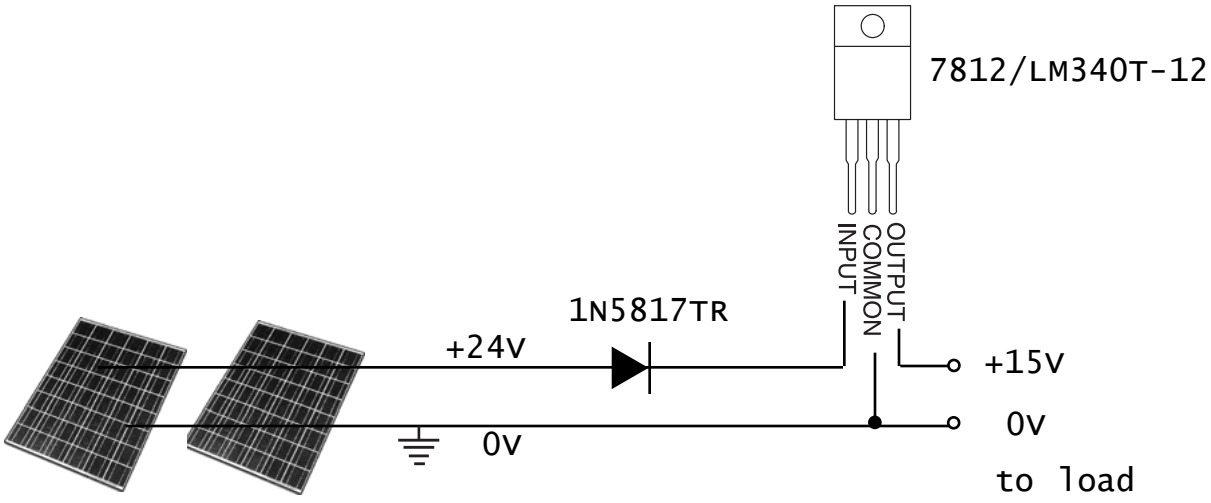
voltage regulators

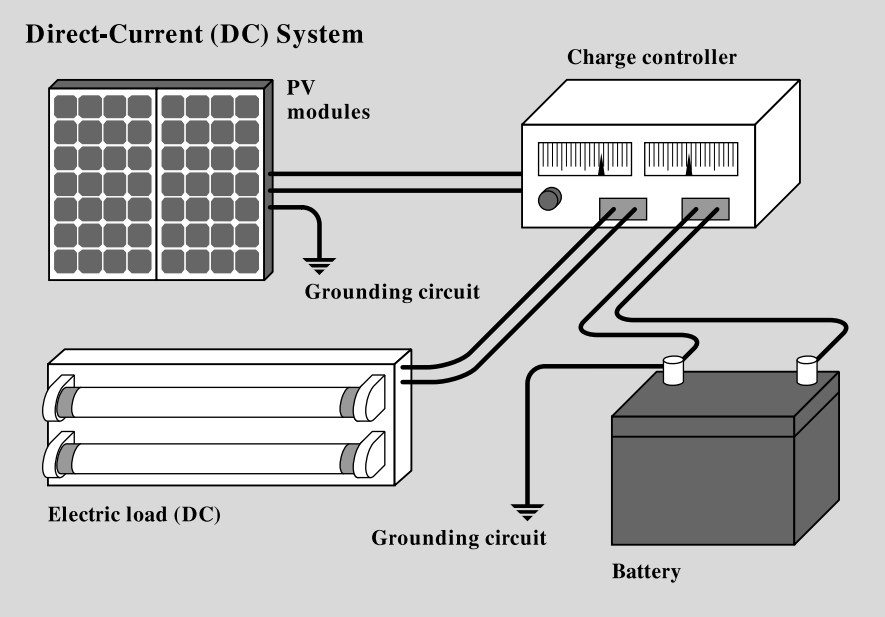
chips such as the 7805,7809,7812/LM340T-12 and 7815 can provide simple +5V, +9V, +12V, and +15V supplies respectively for your solar panel circuits, as long as they are regulating a high voltage down to a lower one. you can find them on digikey.com for less than $1.

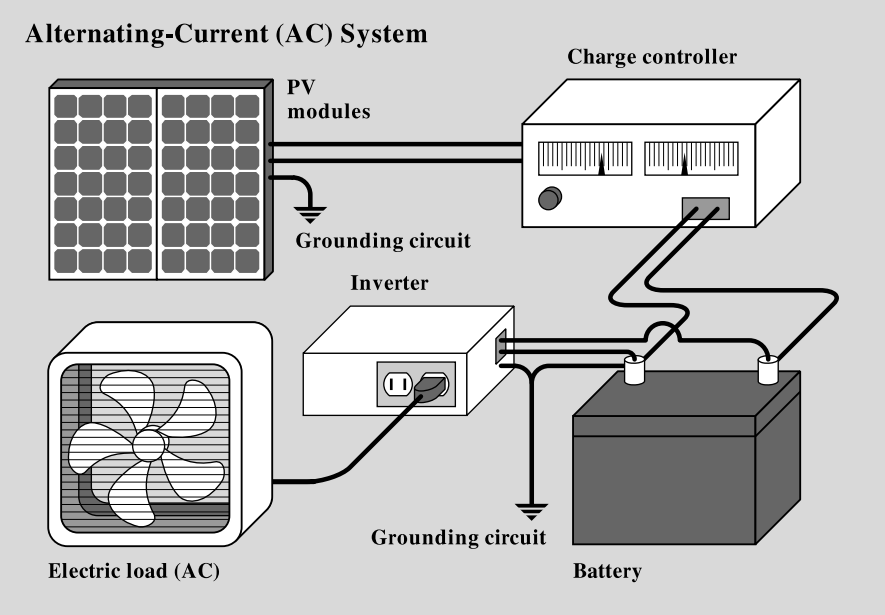




ac & dc configurations

for larger projects call for the use of a ‘charge controller,’ a device that optimizes the charging of the battery in order to decrease time between uses increase its lifecycle.”

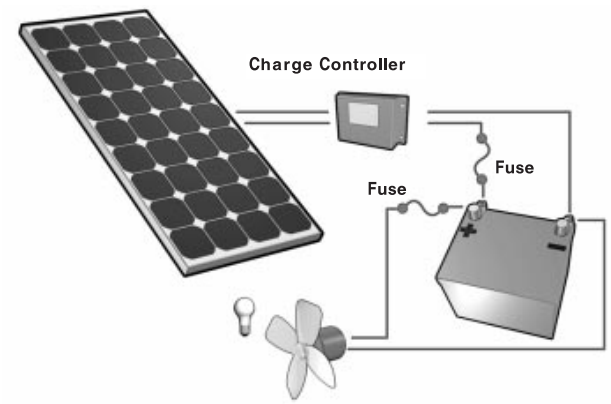




source: US DOE

"other implementations of charge-controlled solar arrays."

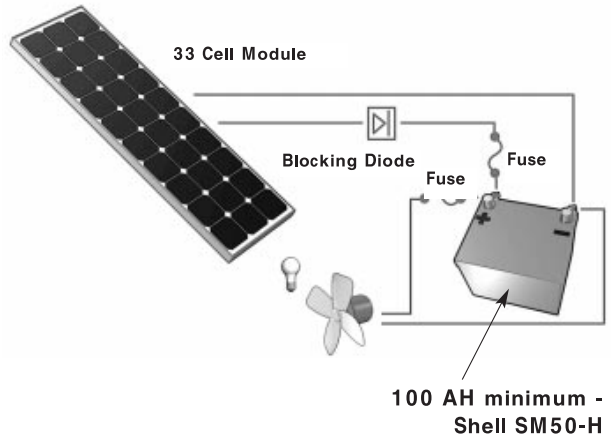
Typical Battery Charging Systems



There are three common types of solar module and battery systems: battery charging using a charge controller, battery charging using a self-regulating solar module, and battery trickle charging.

7.1 Using a Charge Controller

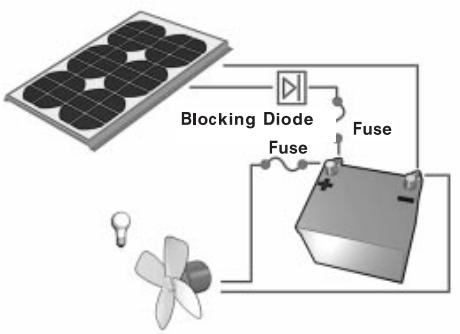
The charge controller protects the battery from overcharging by the solar module. The controller is connected in the circuit between the solar module and battery. Connect wires from the (-) and (+) terminals of the solar module to the corresponding terminals of the controller. Connect wires from the (-) and (+) terminals of the battery to the corresponding terminals of the controller. Always fuse the connections at the battery for safety. Refer to the module rating label (on module) for recommended fuse size. Also, refer to the charge controller owner's manual.



7.2 Using a Self-regulating Solar Module (Shell SM50-H)

In operation, the charging current provided to the battery by a self-regulating solar module decreases as the battery voltage increases; thus, a battery at a low state of charge will accept more charging current than one which is at or near a full state of charge. If the system is used during the day, the charging current will continually adjust to replace the energy used.

Model Shell SM50-H has 33 solar cells wired in series and 18 self-regulating when connected to a battery that is a minimum of 100 AH. **To avoid overcharging the battery it is important to have the same electrical consumption each day**. The module is connected in parallel with the battery. Connect a wire from the (-) terminal of the solar module to the (-) terminal of the battery. Next, connect a wire from the (+) terminal of the solar module to the (+) terminal of the battery. A blocking diode can be used to prevent the discharge of the battery through the solar module during cloudy periods, at night, or under covered storage. Select a diode at least twice the open circuit voltage and short circuit current of the system. A Schottky® barrier diode is preferred. Always fuse the connections at the battery for safety. Refer to the module rating label (on module) for



7.3 Trickle Charging

A small module (5 to 10 watts) is often used to maintain a charge in a 50 to 100 AH battery. The module is connected in parallel with the battery. Connect a wire from the (-) terminal of the solar module to the (-) terminal of the battery. Next, connect a wire from the (+) terminal of the solar module to the (+) terminal of the battery. A blocking diode can be used to prevent the discharge of the battery through the solar module during cloudy periods, at night, or under covered storage. Select a diode that is at least twice the open circuit voltage and short circuit current of the system. A Schottkyd barrier diode is preferred. Always fuse the connections at the battery for safety. Refer to the module rating label (on module) for recommended fuse size.

source: Shell Solar

“a brief overview

of solar panel h+s is summed well in this excerpt from anoth Shell Solar document.”

1 Cautions

• The word "module" as used in this Guide refers to one or more solar electric modules.

• Avoid electrical hazards when installing, wiring, operating and maintaining the module.

• A module generates DC electricity when exposed to sunlight or other light sources.

• It is recommended that the module remains packed in the box until time of installation.

• Do not touch terminals while module is exposed to light or during installation. Provide suitable guards to prevent contact with 30VDC or greater. As an added precaution, use properly insulated tools only.

• When installing or working with module or wiring, cover module face completely with opaque material to halt production of electricity.

• Work only under dry conditions, with a dry module and tools.

• Do not stand or step on module.

• Do not drop module or allow objects to fall on module.

• Never leave a module unsupported or unsecured. If a module should fall, the glass can break. A module with broken glass cannot be repaired and must not be used.

• Keep back surface free from foreign objects.

• Since sparks may be produced, do not install module where flammable gases or vapors are present.

• Do not drill holes into module frame as it will void warranty.

• Avoid sharp edges.

• Do not artificially concentrate sunlight on the module.

• It must be assured that other system components do not generate any hazard of any mechanical or electrical nature to the module.

• Module installation and operation should be performed by qualified personnel only. Children should not be allowed near the solar electric installation.

• If not otherwise specified, it is recommended that requirements of the latest local, national or regional electrical codes be followed.

• Use module for its intended function only. Follow all module manufacturer´s instructions. Do not disassemble the module, or remove any part or label installed by the manufacturer. Do not treat the back of the module with paint or adhesives.

• Retain this instruction booklet for future reference.

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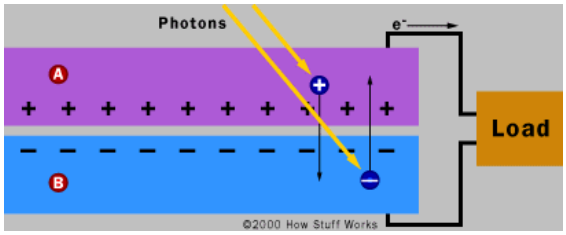
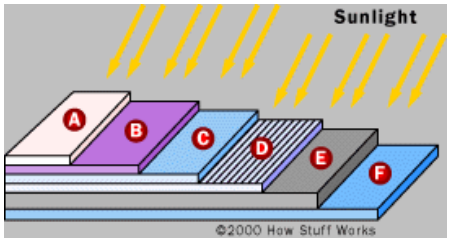
links to theory

regarding solar panels are listed below. I hope you enjoyed the first lecture notes and welcome questions - sloan2 (a t) m i t (d o t) edu”





http://www.oksolar.com/technical/diodes_in_pv_systems.htm

http://www.gosolarpower.com/photovoltaiccells/

http://www.spectrolab.com./prd/prd.asp

http://www.autobahn.mb.ca/~het/energy/solar.html

http://www.eere.energy.gov/pv/onlineind.html

http://www.eere.energy.gov/erec/factsheets/pvbasics.html

http://www.siemenssolar.co.uk/

http://science.howstuffworks.com/solar-cell4.htm

http://pkys.com/Solar%20power.htm

http://www.astropower.com/glossary.htm